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Modern Methods of Mixing and Placing Concrete

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MODERN METHODS OF MIXING AND PLACING CONCRETE

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D E D I C A T I O N

To My Mother,
Mrs. J. V. Love,
Whose Love and Inspiration I owe so much
This Thesis is Dedicated

A C K N O W L E D G E M E N T

The author acknowledges his indebtedness to Director J. J. Abernethy of the Division of Mechanic Arts for his helpful criticisms and constructive suggestions. The splendid cooperation given by Mr. C. L. Wilson, Superintendent of Buildings and Grounds deserve special mention.

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C O N T E N T S

F O R E W O R D

Cement has certain potential qualities which has made it one of the most widely used materials in the construction industries. These qualities however are effected by the manner of it's use.

The most common use of cement is in concrete. In recent years, the factors which effect the qualities of concrete have been subject to intensive study in both the laboratory and the field. As a results, certain basis principles of concrete making have become well established.

This paper has been prepared to explain these principles and their application to concrete projects. The principles are easily applied regardless of how small or large the project may be. Only the usual equipment is required, with such additional items as can be made readily by contraction or supplied at little expense.

For those who desire a more technical discussion of the subject. The Portland Cement Association publication, Design and Control of Concrete Mixture is available.

CHAPTER I

INTRODUCTION

Concrete is most widely used in structures of a permanent nature. It must, therefore, be DURABLE under the particular condition to which it is exposed. It must be STRONG enough to withstand the loads that are put upon it. In many structures it must be water-tight. During handling and placing concrete must be workable so that it can be readily placed in forms without separation of materials. In both the fresh and harden state, concrete must be uniform to secure economy of materials, to make handling and placing easier. And to obtain uniformity in the completed structure.

Concrete can be made to have a wide range in these qualities. It is therefore possible to produce concrete with the particular qualities which will be most suitable to meet the conditions of any job. These conditions should be considered carefully before concreting is started.

CHAPTER II

WEATHER-RESISTANT AND WATER-TIGHT CONCRETE

Concrete that is exposed to the weather must be of such a quality that it resist the weathering action. If concrete is made so porous that water passes through it or into, the water will have a tendency to leach out some of the binding material. When concrete is very porous and frequently exposed to water, this leaching action may be sufficient to seriously affect the life of the structure. In northern climates, weathering is aggrvated by the alternate freezing and thawing of the absorbed moisture. A powerful force is exerted by the swelling action of the freezing water. The objectionable surface discoloration which sometimes occur are also due to the disolving action of the water of porous materials. Concrete that is to have a long life when exposed to these conditions must be made so that water cannot pass through it. In northern climates it must be very dense so that water is not absorbed. This means that the concrete must be water-tight. Water-tight concrete is required for basement walls, tanks, dams, and other hydraulic structures.

CHAPTER III

HOW AMOUNT OF MIXING WATER AFFECTS WATER-TIGHTNESS AND DURABILITY

When water is mixed with cement it forms a paste which in concrete binds aggregates and fill the spaces between them. The paste is gradually harden through a chemical action called hydration. The aggregates being only an inert meneral filler during the hydration process which takes considerable time, some of the mixing water combines chemically with the cement. "Proper curing" or keeping the concrete damp will cause more water to combine with the cement than when the cement is permitted to dry out. High temperatures cause the action to take place more rapidly than low temperatures.

More water is necessary to make the concrete plastic enough for placing than is required for complete hydration of cement. In time this extra water will usually evaporate leaving small porous or spaces in the concrete. The more extra water used the more numerous will be these air spaces.

When small amounts of water are used in mixing the spaces will be smaller and fewer and will be so well distributed that the concrete will be water-tight. Thus it is seen for water-tight construction and for durability when concrete is exposed to the weather the amount of mixing water must be limited and the concrete must be properly cured to prevent the evaporation of this water until it has had time to combine chemically with the cement.

Another requirement for water-tight and durable concrete is that aggregates of low absorption be used and that the mixtures be so workable that each aggregate particle is thoroughly imbedded in water-tight paste. Most of the commercial aggregates have been washed and screened are suitable for this purpose.

HOW AMOUNT OF MIXING WATER AFFECTS THE STRENGTH

The strength of concrete will depend almost entirely on the strength of the binding paste and its power to hold the aggregates together, assuming the aggregates themselves are of a suitable quality. It is the hydration process that gives the strength to the paste. As already seen the most important factors in the hydration process are the amount of mixing water used and the condition of moisture and temperature during this process. Tests shows that there is a definite relation between amount of mixing water and strength of concrete for a given set of conditions. The less water used the stronger will be the concrete. This is demonstrated in figure one and two.

In figure one will be seen that a single mix may give a wide range in strength, depending on amount of water used to produce the different consistances. It will be noted that as amount of water increased the strength decreased.

Figure two shows that the strength of concrete specimen taken from a wide range of mixes is practically the same. When the same ratio of water to cement is used in each, the consistency of the different specimens is not the same because the proportions and amount of aggregates are not the same. In order to obtain the weather consistencies with the same strength richer mixes are required.

The above discussion that in proportioning concrete mixtures, the important factor is the amount of mixing water. In determining the amount

HOW MUCH MIXING WATER TO USE

that may be used in concrete for a particular job. It is necessary to consider both the exposure to which the concrete is to be subjected and the strength that is required. In structures when the concrete is to be exposed to severe weathering conditions or in which water tightness is important, a low enough water-cement ratio to assure water tight concrete should be selected. Such concrete usually will have ample strength to carry loads that are imposed.

Table I suggests the classes of concrete required for a number of structures and may be used as a guide in selecting water cement ratios. Other structures in the group which represents those of a similar type. For example, suppose a reinforced concrete bridge is to be built in a northern climate where conditions are severe. Although a little of the concrete will be in continuous contact with the water, it will be subjected to rain, snow, freezing, and thawing. Since the sections of the concrete will be reinforced and fairly thin, the water cement ratio indicated in the table is six gallons per sack of cement.

In inclosed structures and in locations where exposure is not severe or when water tightness is not important, the strength of concrete becomes the deciding factor in selecting the water cement ratios when average materials are used and the concrete is moist cured at a temperature of about 70% fahrenheit for at least the first seven days. If less curing is given, a lower water-cement ratio should be used.

CHAPTER IV

PROPORTIONING CONCRETE MIXTURES

Concrete must be workable for the particular job in which it is used. A workable mixture is one that can be easily handled and placed in forms without the materials separating and which will produce a uniform mass in the structure. In such a mixture there will be enough cement water paste to practically float the aggregate and will give good smoothe surfaces, free from stone pockets or honey combing. Mixtures that do not have enough fine aggregates will be harsh difficult to work, and hard to finish. On the other hand, mixtures that contains too much fine aggregate are found to be uneconomical. When the proportion of water to cement is definitely fixed.

WORKABILITY AND CONSISTENCY OF CONCRETE

Consistency is a term used to designate the degree of the wetness of the mixture. Thus, concrete may be referred to as having a dry consistency or a wet consistency. A measure of consistency is the slump test. In this test a truncated cone is used as shown in the illustration, appendix "A". After being filled with fresh concrete, the cone is lifted and the concrete is permitted to slump. The difference is height of the concrete after the test, and the height of the cone is the slump. The specimens shown in figures 1 and 2 of appendix "B", were made with such a slump cone.

For a given consistency there may be a considerable range in the workability, depending upon the water cement ratio of the paste in the mixture and upon the size and proportioning of aggregates. Thus a dry consistency as represented by a 2" slump may be of harsh workability with a large proportion of aggregates but may be made more workable with a large proportion of coarse aggregates. In a very wet consistency as represented by an 8" slump, the materials will have a tendency to separate even when a rather large proportion of sand is used.

Each type of work must be considered carefully by the contractor to obtain the consistency and workability that are best due consideration being given to the condition of placing and the methods of finishing. Proper workability is necessary for complete filling of the forms and consolidations of the mass. It is only for these condition that the quality of the cement paste determines the quality of the cement paste determines the quality of the cement.

After the water cement ratio has been decided upon, the next step is to determine the proportions

PROPORTIONS TO BE USED

of aggregates to cement paste. Since the proportions will vary with the consistency and workability required, and since these will be affected by size grading, and character, no single mix that can be specified for a given water cement ratio. The best method for determining the mix for a specific job is to make or a few trial batches with the given water cement ratio until the desired results are obtained.

The trial batches may be full size batches made in the mixer. Most contractors are accustomed to using certain local aggregate and a little experience with this method of proportioning, can estimate closely the mix that may be used with a given water cement ratio to produce the desired consistency.

When not familiar with materials, the following "rule of thumb" may be applied in determining the approximate proportions for first trial batch. For concrete of fairly stiff consistency the volume of sand plus the volume of coarse aggregate in cubic feet is about equal to the number of gallons of water in mixture. For wetter mixes, the volume of aggregate will be less because more paste is required. This rule may be applied when aggregates are well graded, with maximum size between $\frac{3}{4}$ and $1\frac{1}{2}$ inches. For larger aggregate, somewhat more of the coarse aggregate can be used.

When the first trial batch is made a glance into the mixer will usually show whether the concrete is too wet or too stiff, the adjustment may be made in the batch by adding more aggregate if the concrete is too wet or by adding cement and water in the specified proportions if the concrete is too stiff.

The concrete should then be placed in the forms, the ease of placement and any tendency of the materials to separate being observed. Usually a few adjustments in proportions of the succeeding two or three batches will be sufficient to obtain the best combination of materials keeping water cement ratio constant.

CHAPTER V
CORRECTION FOR MOISTURE IN AGGREGATE

Aggregates as used on the job nearly always contains appreciable amount of free moisture. This must be considered as a part of the mixing water and subtracted from the water which is added to the batch. Under average conditions moist sand will contain $\frac{1}{2}$ gallons of free water per cubic foot of sand, while moist gravel or stone will contain about $\frac{1}{4}$ gallon per cubic foot. These amounts may be assume for the average job. If more accurate results are desired, the exact amount of water may be determined by test.

The correction for moisture may be illustrated by an example. Assume that six gallons of water per sack of cement is specified and that a medium consistency required. The operator may estimate the mix for the first trial batch from past experience or by rule of the thumb. Since a medium consistancy is required, the total volume of fine aggregate and coarse aggregate will be somewhat less than the number of gallons, say about $5\frac{1}{2}$. The approximate mix for the first trial batch may then be taken as 1:2½:3 as measured by damp, loose volumes.

For a one sack batch, the sand will contain $2\frac{1}{2} \times \frac{1}{2}$ or $1\frac{1}{4}$ gallons of water and the coarse aggregate $3 \times \frac{1}{4}$ or $\frac{3}{4}$ gallons, a total of 2 gallons. The water to be added to the batch will, therefore be $6-2 = 4$ gallons per sack of cement. Small amount of cement water or aggregates to this batch may be necessary so that it can be used in the work, but indicated corrections can be made in the next batchs. If the first batch is wetter than is necessary, more aggregate can be used. In this example, suppose that the operator finds he can use a stiffer concrete for the job and can increase the aggregate proportions to a 1:2½:3½ mix. The total correction for moisture in the sand will now be $2\frac{1}{2} \times \frac{1}{2}$ or $1\frac{1}{4}$ gallons and for coarse aggregate $3\frac{1}{2} \times \frac{1}{4}$ or 7/8 gallons a total of 2 1/8 gallons. The amount of water to add to the batch will then be 6-2 1/8 = 3 7/8 gallons per sack of cement.

Usually it will not require more than three or four trial batches to determine the best combination of materials. Each time the aggregate proportion are changed, the corresponding adjustments for moisture carried by aggregate should be made in the water added to the batch. After the job is running smoothly, if a sudden change occurs in consistency of the concrete it may be due to a change in the moisture held by the aggregates or to a change in the size used. A new test for moisture should be made and the mix corrected to correspond.

The relative proportions of fine and coarse aggregate that can be used will be affected by the grading and by the shape and size of the particles have less surface area to be coated with cement paste than aggregate, therefore, has a tendency to permit greater yield of concrete from a given amount of cement. However, if too much coarse material is used, harsh mixes results and the cost of handling and finishing is increased. Honey combing is also produced by such mixes.

COMBINATION OF FINE AND COARSE AGGREGATE

Increasing the proportions of fine materials give smoother working mixes, but excessive proportions of sand should be avoided as the fine material requires more cement paste to produce a given consistency and thus reduces the yield. While the best combination will vary with materials, the range of proportions that can be used with economy is rather narrow and can be easily recognized. For average conditions the amount of sand will be about 2/3 that of the coarse aggregate.

PROPORTIONS OF AGGREGATE TO CEMENT

The total amount of aggregate that can be used with a given amount of cement and its fixed proportions of water will depend upon it's consistency required by the conditions on the job. A stiff mix permits a large proportion of aggregate per volume of the cement-water paste while a more fluid mix will require a smaller amount of aggregate and hence a larger proportion of cement. Too stiff a mix should be avoided as it increases the cost of handling and placing.

A proper balance between the various factors should be obtained, with the results that the concrete will be neither harsh nor honeycombed on the one hand and over wet and segregating on the other. Both extremes tend to produce porous, non-durable concrete. An important advantage of water cement ratio method to the contractors is that materials may be proportioned to make handling and placing easier, thus reducing the cost of these operations.

Many tables showing the quantities of materials required to produce a cubic yard of concrete with various proportions have been published. While useful for estimating purposes, they have been published. While useful for estimating purposes, they do not give as accurate results as can be obtained by taking the characteristics of the particular materials into account. A more accurate method is coming into general use based on assumption that in plastic mixtures the voids in separate materials as completely filled. The volume of concrete produced by combining the materials is therefore equal to the volume of the solids in the cement, plus the volume of water. The volume of solid material in one sack of cement is 0.49 cubic feet. The volume

The volume of solid materials in the more common aggregate may be found by dividing the weight of the aggregate by the factor 166 for other aggregates, this factor may be determined by test.

To apply this method it is necessary to know the weight of the source and the coarse aggregate used with each sack of cement. These weights can be determined by using a cubic foot box as recommended in a later paragraph for calibrating the volumes of wheel barrows. This box is loosely filled with damp aggregates as used on the job and the contents then weighed. The materials may be placed in pails and weighed by means of a small spring scale when larger scales are not available. Since the aggregates contains moisture this must be subtracted to obtain the weight of dry aggregate in each cubic foot as measured.

The method of determining the volume of concrete produced may be illustrated by an example, using the problem listed on page 19 of this thesis: Assume that weights 92 lbs. per cubic foot, since each cubic foot contains $\frac{1}{2}$ gallon of surface water or about 4 lbs. (water weighs 8.33 lbs. per gallon), the weight of dry sand in a cubic foot is 92-4 = 88 lbs. Assume also that the coarse aggregate weighs 100 lbs. per cu. ft. and since it contains $\frac{1}{4}$ gallon of water or about 2 lbs. the weight of dry coarse aggregate in a cubic ft. is 100-2 = 98 lbs. Then with the 1:$2\frac{1}{2}$:$3\frac{1}{2}$ mix and 6 gallons of water the volume of solid in each material used.

Material used with a sack of cement is:

Volume of solids in one sack of cement = .49 cu. ft.

Volume of solids in fine aggregates = $\frac{88 \times 2\frac{1}{2}}{166}$ = 1.33 cu. ft.

Volume of solids in coarse aggregate = $\frac{98 \times 3\frac{1}{2}}{166}$ = 2.07 cu. ft.

Volume of water = $\frac{6}{7\frac{1}{2}}$ .... .80

Total volume of concrete .... 4.69 cu. ft.

Thus one sack of cement produces 4.69 cu. ft. of concrete. The cement required for one cubic yard of concrete is therefore $\frac{27}{1469}$ = 5.75 or $5\frac{3}{4}$ sacks. Since $2\frac{1}{2}$ cu. ft. of sand and $3\frac{1}{2}$ ft. of coarse aggregate are used with each sack of cement, the amounts of aggregates required for one cubic yard of concrete will be $\frac{5\frac{3}{4} \times 2\frac{1}{2}}{27}$ = .53 cu. yds. of sand and $\frac{5\frac{3}{4} \times 3\frac{1}{2}}{27}$ = .75 cu. yds. of coarse aggregate as measured on the job by loose volume.

The quantities of materials in concrete mixture may also be determined accurately by making use of the fact that the volume of concrete produced by any combination of materials so long as concrete is plastic, is equal to the sum of the absolute volume of cement plus the absolute volume of the aggregate plus the volume of water.

This can be computed from the weight per unit volume and the apparent specific gravity as follows:

$$\text{Absolute volume} = \frac{\text{unit weight}}{\text{apparent sp. grav.} \times \text{unit wt. of } H_2O}$$

This method can best be illustrated by an example. Suppose the concrete batch consist of 1 sack of cement (94 lbs.), 22 cu. ft. of dry find aggregate weighing 110 lbs. per cu. ft. and 36 cu. ft. of dry coarse aggregate weighing 100 lbs. per cu. ft. and is mixed with water cement ratio of 7 gallons per sack. The apparent specific gravity of the cement is usually about 3.1 and of the more common aggregates about 2.65 the volume of concrete produced by the above mix is calculated as follows:

Cement = 1 cu. ft. @ $\frac{94}{3.1 \times 62.5}$ = .49 cu. ft. absolute volume

Fine ag. = 2.2 cu. ft. @ $\frac{110}{2.65 \times 62.5}$ = 1.46 Ditto

Coarse ag. = 3.6 @ $\frac{100}{2.65 \times 62.5}$ = 2.18 Ditto

Volume of H_2O = $\frac{7.0}{7.5}$ = $\frac{93}{5.06}$ cu. ft.

Thus 1 sack of cement produces 5.06 neglecting absorption or losses in manipulation. The cement required for 1 cu. yd. of concrete is therefore $\frac{27}{5.06}$ = 5.34 sacks or 1.33 barrels.

The quantity of fine and coarse aggregates required can be found from simple compution based on the number of cu. ft. used with each sack of cement. Thus, for the fine aggregate $\frac{5.34 \times 2.2}{27}$ = .43 cu. yd. and for the coarse aggregate $\frac{5.34 \times 3.6}{27}$ = 7.1 cu. yd.

CHAPTER VI

SELECTING OF MATERIALS

Cement should conform to the standard specifi cation and tests of the American Society for test-
CEMENT ing materials.

The water should be suitable for drinking un- less it is known by test or experience that other
WATER waters are satisfactory. Sea water should not be used for mixing concrete on account of the danger of cohesion of steel reinforcement.

All aggregates should consist of inert materials that are clean, hard, strong, and double. The particles should not be crated with clay or dirt
AGGREGATES since this prevents proper bonding of the paste. Weak friable or laminated materials are undesirable. Shale and stones laminated with shale are especially to be avoided. A visual in- spection will usually disclose any weakness in the coarse aggregate. A good specification for aggre- gates is that they meet the requirements of the

tentative specifications for concrete aggregates of the American Society for testing materials.

The American Society of testing materials specifies that from 2 to 30 percent of fine aggregate pass a 50 - mesh seive. The maximun size of aggregate is governed by nature of the work. In thin slabs or walls the largest pieces of aggregates should never exceed about 1/5 to ¼ the thickness of the section on concrete being placed. In reinforced concrete, specification usually limit the maximum size to ¾ of the minimum clear spacing between reinforcing bars.

MEASUREMENT OF MATERIALS

The proper and accurate measurement of all the ingredients used in concrete is necessary for production of uniform batches of a given quality. Accurate measurement is also of assistance in producing the most economical results and prevents variations in the mix that would cause delay to progress the work.

MEASURING EQUIPMENT

Selecting of equipment must of course, depend primarily upon the type and extent of the work and no general recommendations can be made regarding it. The more extensive the work the more severe the requirements as to uniformity, the more important become the layout and equipment. On many jobs, if full advantage is taken of the possibilities of properly designed mixes. It would no doubt be found economical to install carefully adequate equipment. Batcher plants are now very common. In batchers where measurement of aggregates is made by volume, allowance must be made by volume. Allowance must be made by the bulking caused by moisture.

On small projects many contractors have secured good control of the materials by weighing the aggregates on ordinary platforms' scales.

Some contractors whose jobs are too small for batching plants used the wheel barrow. By calibrating wheel barrows so that their capacities are known and providing accurate means of measuring the water. Satisfactory results are secured. For convenience in determing the volume of the wheel barrows, a measuring box 1 ft. square by 1 ft. high may be used.

CHAPTER VII
MIXING CONCRETE

Practically all concrete even for small jobs is mixed by machine in batch mixes of various capacities, from two cu. ft. to four cu. yds. per batch. Mixers have been brought to a high state of efficiency, producing satisfactory results at a minimum cost of labor and power. Small changes in speed of the mixer have little effect on the strength of the concrete as it is largely the time element of mixing and not the rate of rotation of the mixer that influence the strength and quality. The mixer should never be overloaded above the rated capacity as such overloads prevent thorough mixing. If increase output is needed it should be obtained by a larger mixer.

Test show that strength is increased by longer periods of mixing. Typical values from these tests are shown in chart 2 of the appendix. The rapid increase in strength for different periods of mixing up to about 2 minutes can be seen on the curve.

For instance, concrete of the usual quality mixed for that period is from 20 to 35% stronger than concrete mixed on 15 seconds.

In the test from which these curves were constructed it was found that through mixing also makes for more uniform concrete. Furthermore through mixing gives increased workability, which in turn requires less labor in placing or permits the use slightly larger quantities of aggregates with a given quantity of cement and water in their fixed ratio. A further advantage of thorough mixing is that it is of great assistance in securing water tight concrete.

In transporting concrete from the mixer to the forms, care should be taken to avoid separation of materials. Smooth run ways are desirable when wheel barrows and buggies are used. The constant jarring of concrete causes the heavy particles of aggregates to sink and causes cement and water to rise to the surface. Well designed chutes placed at proper angles will avoid segregation of a workable mix. Generally the slope should be from 1:2 and 1:3. Improvised wood chutes are usually made too flat and shallow to be satisfactory.

No element in the entire cycle of production requires more care than the final operation of placing

PLACING CONCRETE

concrete at the ultimate point of deposit. Before placing concrete, all debris and ice should be removed from the places to be occupied by the concrete and the forms should be thoroughly wetted (except in freezing weather) or oiled. Temporary openings should be provided when necessary to facilitate cleaning and inspection immediately before depositing concrete. These should be so placed that excess water used in flushing the forms may be drained out.

With a well designed mixture delivered with proper consistency and without segregation, placing

PREVENTION OF SEGREGATION

of concrete is greatly simplified; but even in this case care must be exercised to further prevent segregation and to see that materials flow properly into corners and of forms and around reinforcement. Constant supervision is essential to insure such complete filling of form and to prevent the rather common practice of depositing continuously at one point, allowing the cause segregation especially of water and fines from the rest of the mass. An excessive amount of tamping or puddling in the forms will also cause the materials to separate. When the concrete is properly proportioned the entrained air will escape and the mass will be thoroughly consolidated with very little puddling. Light spading of concrete next to the forms will prevent honeycombing and make surface finishing easier.

In placing concrete in deep layers a gradual increase in the water contents of the upper portions is quite certain to result from the increase pressure on the lower portions. The excess water should be worked to a low point, without actually causing a flow and removed. It should be remembered that excess water in the upper layer is just as objectionable as excess mixing water.

Attention is called to the significance of a layer of laitance on a section of concrete. It has been a common assumption that if this laitance is completely removed all danger has been eliminated, in fact, specification frequently place considerable stress on it's removal. Laitance however can only form from the presence of excess water, which means that the upper portion of the concrete will be porous, and the removal of a small layer of laitance still leaves several inches of porous concrete through which water will pass even under moderate pressure. The effect of this porous layer at the top of each days work can be seen in many structures subject to water pressure. The lower portion of the layer is found to be hard and dense while the upper portion efflorence due to passing water.

PREVENTION OF LAITANCE

C O N C L U S I O N

The principles laid down in this thesis will meet the requirements for a successful design on any job, large or small. The proper balance between the four essentials STRENGTH, DURABILITY, ECONOMY, and WORKABILITY will be attained. The mixture will be placable in the proper degree; it will represent an economical use of available materials, and when hardened will provide the necessary strength and resistance to weathering agencies.

F I N I S H

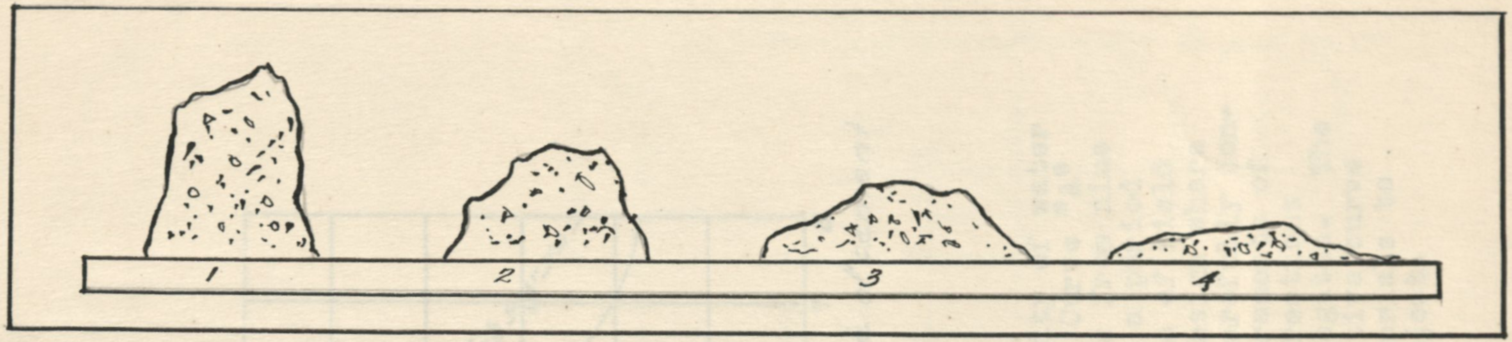
EFFECT OF AMOUNT OF MIXING WATER ON STRENGTH OF CONCRETE

Fig. 1 - Strength Decreases as Amount of Mixing Water Increases

SPECIMEN	1	2	3	4
Water, gallons per sack of cement	$5\frac{1}{2}$	6	$6\frac{3}{4}$	$7\frac{1}{2}$
Mixture by dry, compact volume	1-2-$3\frac{1}{2}$	1-2-$3\frac{1}{2}$	1-2-$3\frac{1}{2}$	1-2-$3\frac{1}{2}$
Strength, lb. per sq. in. at 28 days	3900	3570	3090	2360

EFFECT OF AMOUNT OF MIXING WATER ON STRENGTH OF CONCRETE

Fig. 2 - Equal Amounts of Mixing Water Produce Same Strength



SPECIMEN	1	2	3	4
Water, gallons per sack of cement	$6\frac{3}{4}$	$6\frac{3}{4}$	$6\frac{3}{4}$	$6\frac{3}{4}$
Mixture by dry, compact volume	$1-2\frac{1}{4}-4$	$1-2-3\frac{1}{2}$	$1-1\frac{3}{4}-3$	$1-1\frac{1}{2}-2\frac{1}{2}$
Strength, lb. per sq. in. at 28 days	3250	3130	3060	3070

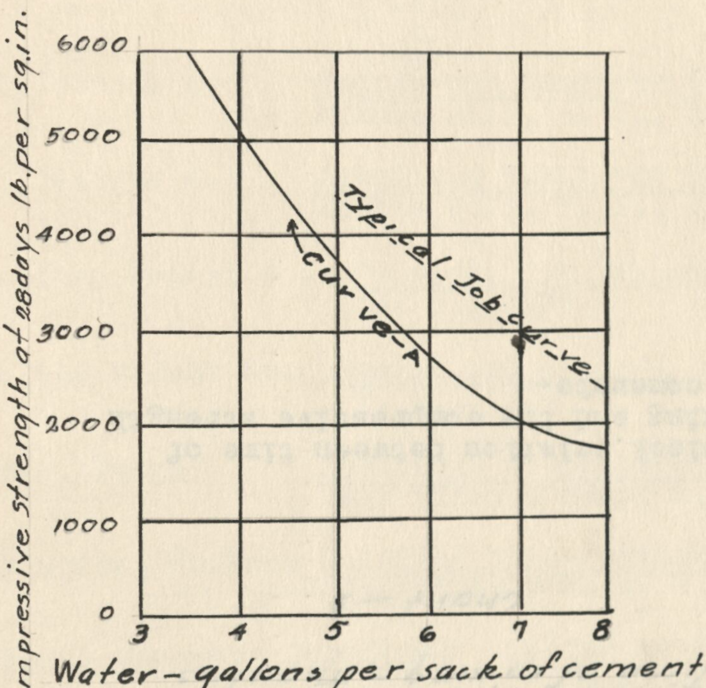


chart-1

Chart 1 - Effect of quantity of water on strength of concrete. Curve "A" is based on average values from nine series of tests made over a period of four years. In absence of field test it may be used for design where water cement ratios are carefully controlled by accurate measurements of materials with proper corrections for water carried by aggregates. The job curve is a representative curve obtained from test of materials to be used on a specific project.

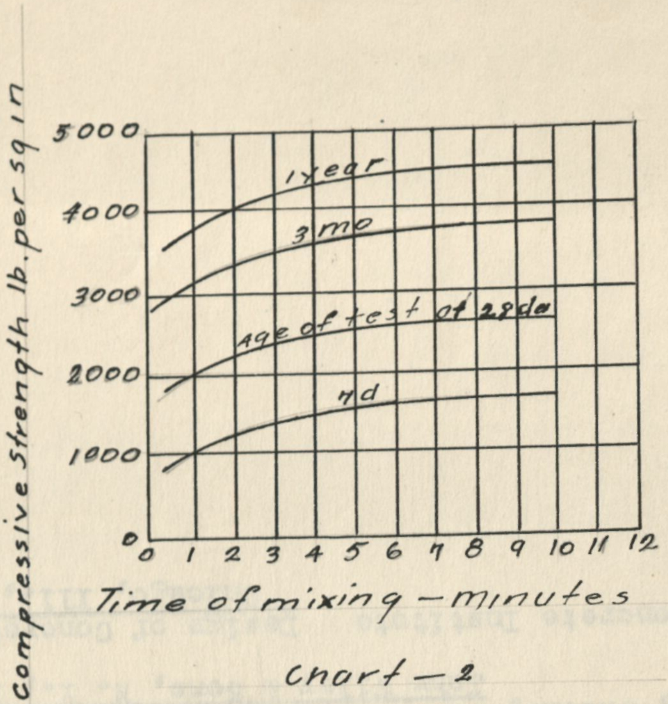


Chart - 2

Typical relation between time of mixing and the compressive strength of concrete.

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